(12) UK Patent Application (19) GB (11) 2 083 974 A

(21) Application No 8126826
(22) Date of filing 4 Sep 1981
(30) Priority data
(31) 80/28560
(32) 4 Sep 1980
(33) United Kingdom (GB)
(43) Application published
31 Mar 1982
(51) INT CL³
H04R 3/00
(52) Domestic classification
H4J 30F 31H 35H G
(56) Documents cited
GB 1585759
(58) Field of search
H4J
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(54) Moving coil loudspeaker

(57) The bass response of a moving coil loudspeaker is extended by superimposing on the acoustic signals supplied to the voice coil (6) a compensation signal derived from photo-electric sensing of the displacement of the voice coil from its rest position, utilising reflection of light from a diffusely reflecting surface of the voice coil former (2) which has varying characteristics in the direction of coil displacement. The compensation signals are applied as positive feedback signals to the voice coil to produce forces on the latter which correct for the non-linearity of the voice coil displacements due, for example, to compression effects of the loudspeaker diaphragm oscillation. Since the compensation signal is zero in the rest position of the coil the additional power dissipation introduced by the compensation signals is minimal.

Fig.1

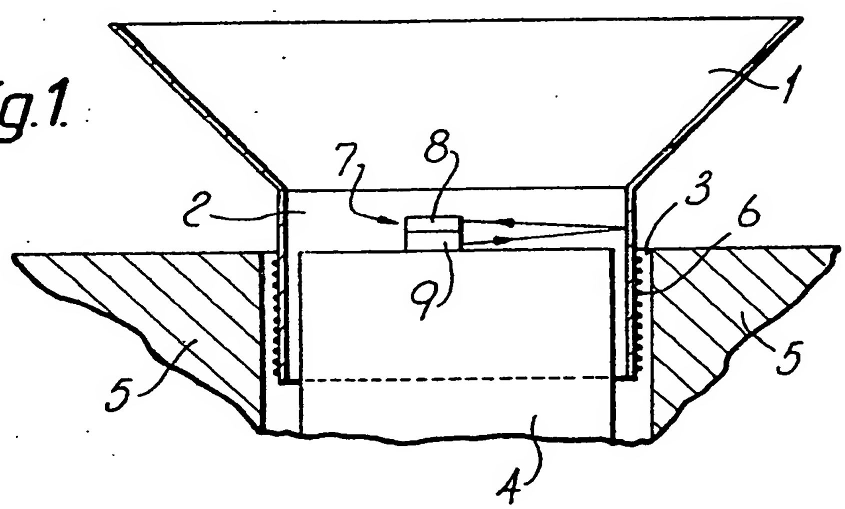

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Fig.1.

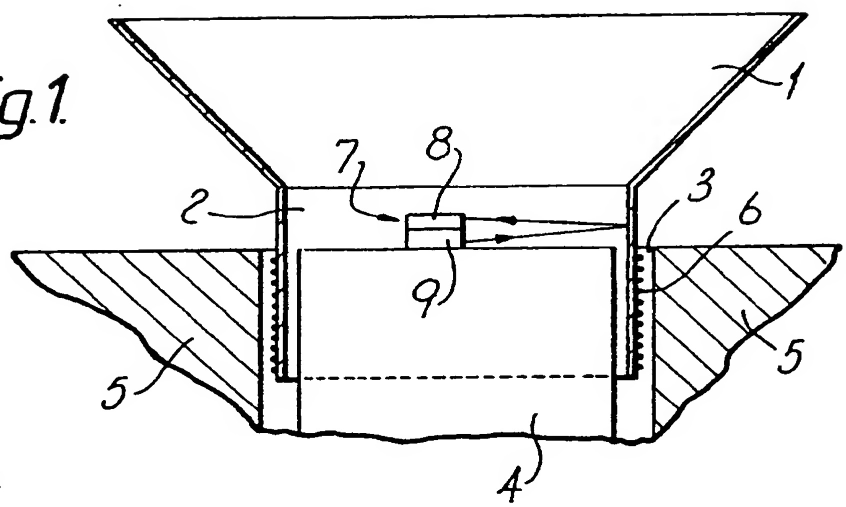


Fig.2.

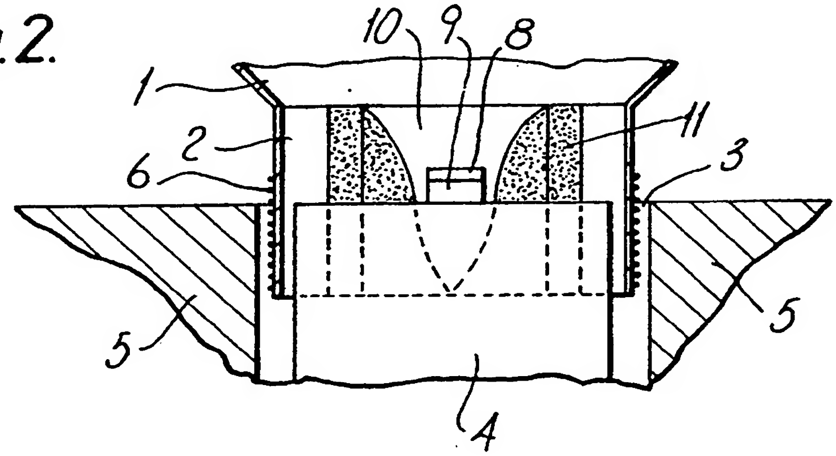


Fig.3.

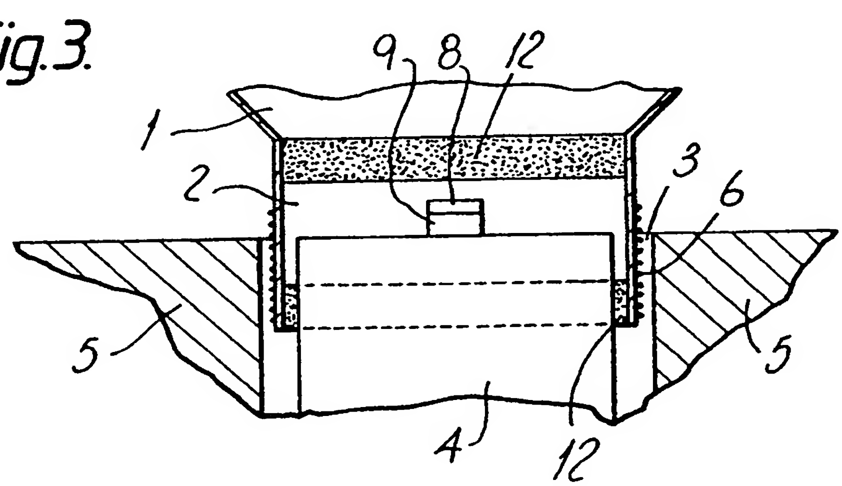


Fig. 4.

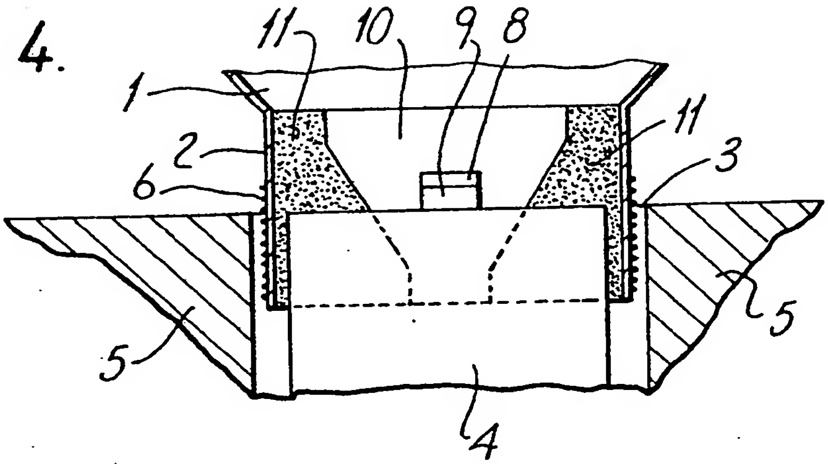
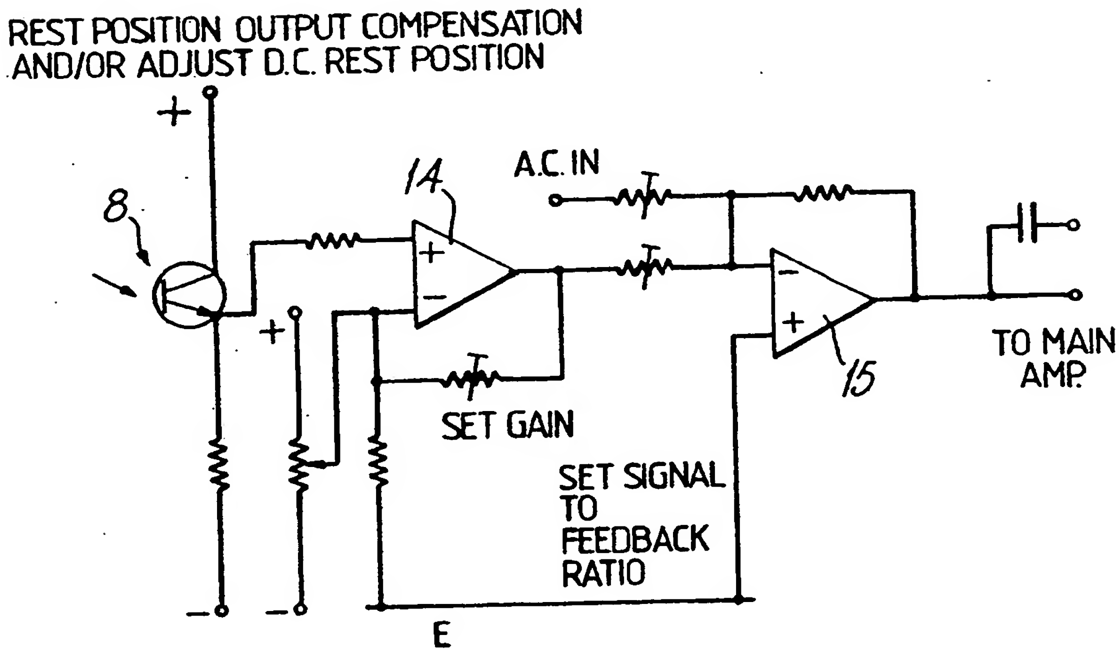

11
10
9
8
1
2
6
11
3
5
5
4

Fig. 5.


REST POSITION OUTPUT COMPENSATION
AND/OR ADJUST D.C. REST POSITION
+
8
14
A.C. IN
+
SET GAIN
SET SIGNAL
TO
FEEDBACK
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15
TO MAIN
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E

SPECIFICATION

Moving coil loudspeaker

This invention relates to moving coil loudspeakers.

Moving coil loudspeakers have a voice coil carried on a former which is attached to the cone or diaphragm of the loudspeaker. The voice coil is suspended in a magnetic flux gap between pole pieces of a permanent magnet, and in response to acoustic signals fed to the coil the latter oscillates in the flux gap and drives the loudspeaker cone or diaphragm.

The frequency response of a moving coil loudspeaker, particularly at low frequencies (the bass response) is affected adversely by non-linearity in the relationship between the forces acting upon the voice coil and the displacement of the voice coil from its rest position. Such non-linearity arises, for example, through the fact that as the coil moves further into the flux gap the loudspeaker cone or diaphragm compresses the air in the magnet enclosure, giving rise to a force resisting the displacement of the coil. Similarly, as the voice coil tends to move out of the air gap the air trapped beneath the diaphragm or cone is rarified and the displacement of the coil is again resisted. These effects, combined with non-linearity in the suspension of the voice coil and the loudspeaker diaphragm or cone, militate against the linear coil displacement characteristic which is ideally required.

A known method of compensating for the above mentioned non-linearity is to provide an additional coil on the same former as the voice coil and to supply this additional coil with a direct current signal (H. Lipschutz, Hi Fi News, April 1980, Page 63). The direct current flowing in the additional coil exerts a force on the former which can be arranged to compensate for the reaction force resulting from compression of the air in the loudspeaker enclosure. More than one such additional coil may be mounted on the voice coil former so that both a "pushing" and a "pulling" force is extorted on the voice coil former to compensate for the reaction forces arising from large displacements of the voice coil. A practical disadvantage of such known arrangements using DC-fed additional coil is that the continuous current flowing in the additional coil or coils generates heat additional to that generated in the voice coil in use of the loudspeaker, and exacerbates the heat dissipation problem. Furthermore, the positioning of the or each additional coil has to be accurate for optimum effect, and this inevitably increases the cost of the loudspeaker.

The present invention seeks to provide a moving coil loudspeaker in which a degree of compensation for non-linearity can be achieved without resorting to the use of an additional DC-fed coil.

It is known, for example from French Patent Specification No. 2296985, to provide a moving coil loudspeaker in which a "negative feedback" compensation signal is superimposed on the acoustic signal fed to a voice coil, the compensation signal being derived from electro-optical sensor means responsive to the position of the voice coil relative to its rest position in the magnetic field of the loudspeaker magnet, in a sense to compensate for distortion. Such negative feedback compensation, while reducing distortion in the coil response, does not counter the non-linearity which results from the compression of air in the magnet enclosure.

The present invention provides a simple solution to the problem of compensating for non-linearity in loudspeaker response resulting from air compression effects by arranging for a compensation signal derived from a voice coil position sensor to be superimposed on the voice coil signal as a positive feedback signal.

The positive feedback compensation signal produces a force on the voice coil which counters the forces resulting from compression effects of the loudspeaker cone or diaphragm and from non-linearity of the coil suspension.

Any convenient sensor means may be employed to sense the movement of the voice coil. In a preferred embodiment the sensor means are electro-optical and comprise a photoelectric detector and a light source mounted on a central polepiece of the loudspeaker magnet, the voice coil former being provided with a diffusely reflective internal surface the reflecting characteristics of which vary in the direction of coil displacement to produce the desired compensation signal.

An advantage of the photoelectric detection system of the present invention is its essential simplicity, since expensive precision optics are not required in association with the light source or the detector.

In one embodiment of the invention the voice coil former is provided with a pattern of non-reflective areas which carry in circumferential width relative to the reflective areas as a linear or non-linear function of distance in the direction of coil displacement.

The compensation signal may be zero in the rest position of the coil, in contrast to loudspeakers in which an additional direct-current coil is employed. If desired, however, the actual rest position adpoted by the voice coil may be compensated by including in the compensation signal a direct-current component.

The invention will be further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic axial sectional view of a moving coil loudspeaker according to a first embodiment of the invention;

Figures 2-4 are axial sectional views corresponding to Figure 1 and illustrating different variants of the embodiment shown in Figure 1, and

Figure 5 is a schematic diagram of a circuit for deriving a compensation signal in a loudspeaker according to the invention.

Figure 1 illustrates the essential elements of a moving coil loudspeaker having an oscillatory diaphragm or cone 1 which carries a tubular former 2 suspended coaxially in an annular air gap 3 between concentric pole pieces 4, 5 of a permanent magnet (not shown). The former 2 carries a voice coil 6 which is located in the magnetic flux of the air gap 3 so that oscillations are induced in the coil 6 and, therefore, in the former 2 and cone 1, when an

acoustic signal is fed to the coil 6.

To compensate for non-linearity in the loudspeaker response, particularly the bass response, arising, for example, from compression and rarefraction forces resulting from the displacements of the loudspeaker cone 1, a positive feedback compensation signal is superimposed on the acoustic signal fed to the voice coil 6. The compensation signal is dependent upon the position of the voice coil relative to this rest position in the air gap 3.

In the embodiment illustrated in Figure 1 the compensation signal is derived by direct sensing of the position of the voice coil 6 using optical means. An optical transducer unit 7 is mounted on the central pole piece 4 and comprises a phototransistor 8 superimposed upon a light emitting diode 9. The light emitting diode 9 directs light onto the internal surface of the coil former 2, this surface being ideally treated or coated so as to be diffusely reflective. Light reflected from the former 2 is detected by the phototransistor 8, as illustrated diagrammatically in Figure 1. The output signal of the phototransistor 8 will be proportional to the intensity of the light reflected from the internal surface of the former 2, which in turn will be proportional to the amount by which the former 2 projects beyond the end face of the pole piece 4: that is, the output signal of the phototransistor 8 will be dependent upon the displacement of the voice coil 6 from its rest position, and will increase with increasing displacement of the coil.

In the embodiment illustrated in Figure 1 the internal surface of the former 2 is uniformly diffusely reflective and the light emitting diode 9 emits a broad beam. Under these conditions the output signal of the phototransistor 8 will be substantially linearly dependent upon the displacement of the coil former 2. By suitable selection of the light emitting characteristics of the source 9 and the reflecting characteristics of the internal surface of the former 2 it is possible to predetermine the relationship between the output signal of the transistor 8 and the displacement of the voice coil 6.

Three alternative variants of the embodiment illustrated in Figure 1 are shown by way of example in Figures 2, 3 and 4, in which the same reference numerals have been used to designate the same or corresponding component parts. In Figure 2, the internal surface of the coil former 2 is provided with a non-linear pattern of reflective areas 10 and non-reflective areas 11 and the light source 9 emits a fan shaped beam, that is, a beam which is narrow in the longitudinal direction of oscillation of the coil 6. With this arrangement the area of light reflecting surface presented to the light beam from the source 9 will be non-linearly dependent upon the displacement of the coil former 2 from its rest position.

In the variant illustrated in Figure 3 the internal surface of the coil former 2 is provided with non-reflective zones 12 at opposite extremes of its reflective surface zone 10, delimiting the maximum excursion of the voice coil 6. Thus in the rest position illustrated in Figure 3 the beam emitted by the light source 9 lies symmetrically between the two non-reflecting zones 12. With this arrangement the output signal of the phototransistor 8 will be substantially linearly dependent upon the displacement of the voice coil 6 up to the maximum permitted amplitude of oscillation of the latter.

In the variant illustrated in Figure 4 the reflective surface area 10 of the voice coil former 2 tapers in circumferential width linearly between two extreme zones and the light beam emitted by the source 9 is fan-shaped, as in the variant of Figure 2. With this arrangement the area of the reflective surface 10 presented to the light beam emitted by the source 9 will be linearly dependent upon the displacement of the voice coil 6 from its rest position. The output of the phototransistor 8 will increase linearly as the voice coil 6 is displaced into the air gap 3 and will decrease linearly as the voice coil 8 is displaced out of the air gap 3.

In order to produce the desired light emission from the light source 9 a lens or lenses may be associated with the latter, according to whether a narrow pencil beam, a fan-shaped beam, or diffuse radiation is required.

Figure 5 illustrates diagrammatically an electronic signal processing circuit associated with the phototransistor 8 in the illustrated embodiments for producing the required compensation signal. The circuit includes an operational amplifier 14 to which the output of the phototransistor 8 is fed and a second operational amplifier 15 to which the output of the operational amplifier 14 is fed as a positive feedback signal along with the acoustic signal. The output of the operational amplifier 15 is applied to the voice coil 6 and will comprise the acoustic signal with the positive feedback compensation signal superimposed thereon. The magnitude of the compensation signal relative to the acoustic signal can be predetermined by presetting the gain of the operational amplifier 14 and by adjusting the attenuation of the output of the operational amplifier 14.

The rest position of the voice coil 6 may be adjusted or compensated by adjustment of the DC level applied to the phototransistor 8.

It will be appreciated that the sensing of the voice coil displacement may be effected by detecting the position of any component of the voice coil assembly or its former 2 which moves with the voice coil.

In optical systems of voice coil position detection the light source employed may be of any convenient type, such as an incandescent bulb, a light emitting diode, a solid state laser, a "betalight", a neon lamp, or a photoemissive device. The light receiving device illustrated in Figures 1 to 4 as a phototransistor may alternatively comprise a photodiode, a selenium sulphide strip, a photoconductive light-dependent resistor or liquid crystal device, or indeed any photoelectrical transducer capable of transducing an electrical output signal which is dependent on the amount of incident light.

CLAIMS

1. A moving coil loudspeaker in which a compensation signal is superimposed on the acoustic signal fed to a voice coil (6), the compensation signal being derived from sensor means (8,9) responsive to the position of the voice coil (6) relative to its rest position in the magnetic field of the loudspeaker

magnet (4, 5).

characterised in that

the compensation signal is superimposed on the voice coil signal as a positive feedback signal to compensate for non-linearity in the response of the loudspeaker.

2. A moving coil loudspeaker according to Claim 1, characterised in that the sensor means are electro-optical and comprise a photoelectric detector (8) and a light source (9) mounted on a central polepiece (4) of the loudspeaker magnet, the voice coil former (2) being provided with a diffusely reflective internal surface the reflecting characteristics of which vary in the direction of coil displacement to produce the desired compensation signal.

3. A moving coil loudspeaker according to Claim 2, in which the voice coil former (2) is provided with a pattern of non-reflective areas (11) which vary in circumferential width relative to the reflective areas (10) as a linear or non-linear function of distance in the direction of coil displacement.

4. A moving coil loudspeaker according to Claim 2 or Claim 3, in which the voice coil former (2) is provided with circumferential non-reflective zones (12) delimiting the range of maximum excursion of the voice coil (6).

5. A moving coil loudspeaker according to any one of claims 1 to 4, in which the compensation signal is zero in the rest position of the coil.

6. A moving coil loudspeaker according to any one of Claims 1 to 4, in which the compensation signal includes a direct-current component to correct the rest position of the coil.

7. A moving coil loudspeaker substantially as herein described with reference to and as shown in the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1982.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.